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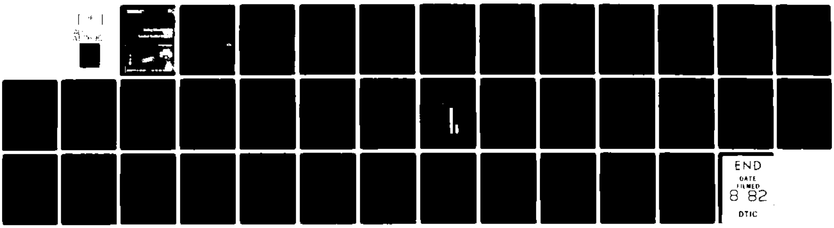

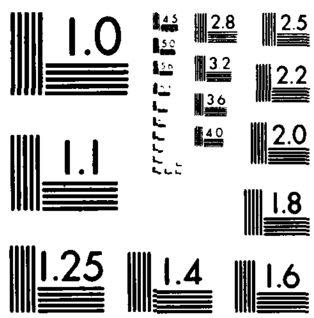


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FACING UNCERTAINTIES
ABOUT
COMBAT SERVICE SUPPORT

by

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National Security Affairs Issue Paper Series 82-2



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## FOREWORD

This second National Security Affairs Issue Paper of 1982 addresses the problem of defining US Army requirements for combat service support (CSS) in today's environment. Since the mid-1970s, the Army has experienced steady reductions in its authorizations for CSS manpower. Now, some have serious doubts about the Army's ability to sustain its combat forces in overseas theaters.

Given that a lack of CSS can compromise combat power, why are there uncertainties about the Army's capabilities? Colonel Mooradian suggests several reasons, the most important being the lack of efficient analytical tools for assessing the important relationship between CSS and combat power. Basing Army requests for CSS manpower on dated analytical models failed to convince decisionmakers that these requests were valid. To correct this condition, the author recommends that the Army: reconsider its method of structuring Tables of Organization and Equipment; increase the flexibility of CSS forces; designate a high-level analytical team vested with overall authority for integrating CSS doctrine with other Army doctrine; and most importantly, use sophisticated analytical tools to evaluate Army CSS. To that end, the paper presents a Force Reliability Model as a suggested beginning in that process.

This conceptual model not only has current applicability, but also suggests the possibilities of the modeling approach in determining CSS effectiveness and requirements in various scenarios. All uncertainty can never be removed from the CSS equation, because we cannot know definitively the CSS requirements in all future conflicts. The Army may, however, reduce uncertainty by using approaches similar to the ones proposed in this paper. Colonel Mooradian's paper thus serves well the purpose of this Issue Paper Series--to contribute new insights and background materials to those charged with the responsibilities of US security.

Franklin D. Margiotta

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## ACKNOWLEDGEMENTS

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## EXECUTIVE SUMMARY

Since 1975 the Army has suffered major reductions in its authorizations for active duty combat service support (CSS) manpower. Today, concerned observers are asking: to what extent have these reductions in CSS compromised Army combat power, and what can be done to correct the deficiency? The purpose of this paper is to suggest a methodology for measuring CSS functions in relation to combat power to better illustrate the weighted importance of CSS. One suggested tool to help in defining CSS objectives and in evaluating CSS effectiveness and costs is the Force Reliability Model at Appendix A. Hypothetical data are used to illustrate the methodology, but the formulas are applicable to factual data.

A much-simplified representation of conditions in Europe, this conceptual model has two important variables: (1) assumed sources of CSS--US Army active component units stationed in Europe; host nation support (HNS) already under contract and performing; additional HNS to be provided during mobilization; and US Army reserve component CSS units that are scheduled into Europe--and (2) kinds of combat--peacetime, short war (or initial hostilities), and long war (or subsequent hostilities). The object is to compute an Index of CSS Mission Success, the ratio of the total expected output of CSS in a given scenario to the total demand for CSS. Using hypothetical data, the analysis of CSS in Europe shows the peacetime Index of Mission Success to be 99 percent (100 percent representing complete mission fulfillment) -- this index would be satisfactory unless the small CSS deficit consisted of extremely critical tasks; the short-war Index of CSS Mission Success to be only 38 percent of assumed demand; and the long-war Index of CSS Mission success to be double that of the short-war scenario, but still 25 percent less than assumed demand. Appendix A presents only a synoptic picture of the adequacy of CSS in the three scenarios examined. Appendix B deals with the conceptual underpinnings of the gross variables outlined in Appendix A, shows how to assess the adequacy of a single CSS function or commodity, and discusses the various options for correcting a CSS shortfall.

# FACING UNCERTAINTIES ABOUT COMBAT SERVICE SUPPORT

## TWO QUESTIONS

The US Army faces a problem in combat service support (CSS), but the extent of the problem is obscured by our lack of precise knowledge about the relationships between combat power and support activities. The Army has neither identified CSS functions that are essential to winning a war in Europe nor determined the effects of combat-diminished support. In the absence of reliable data with which to verify the importance of CSS, the Army has suffered a steady reduction in its authorizations for active duty CSS manpower. Today, concerned observers are asking two serious questions: How much have drastic reductions in CSS compromised combat power? What can be done to correct the deficiency? To answer these questions, the Army must adopt a systematic approach that identifies and assigns priorities to critical CSS tasks, and it must find innovative ways of using its CSS troops more efficiently.

## CAUSES OF UNCERTAINTY

The impetus to reduce support spaces while increasing combat spaces came as reaction to the 1967 Soviet manpower buildup in Eastern Europe. The Soviet buildup seemed ominous, especially because it coincided with transfers of US troops to Southeast Asia. Many feared that Europe would lie exposed to Soviet adventurism. In 1969 Secretary of Defense Melvin Laird responded with the Total Force Concept (TFC), giving reserve forces a responsibility almost equal to that of active forces for the defense of Europe. In 1973, Secretary of Defense Schlesinger elevated the concept to policy. At the time, TFC seemed a reasonable solution to sensitive manpower issues because, thanks to the Selective Service System, a steady stream of youth's were coming into the Army, and many of them would eventually become trained soldiers in the reserves. In 1972 no one talked about a war ending before the reserves arrived in Europe; the total force therefore appeared capable of handling any likely emergency in Europe. Thus, the TFC had minor impact upon CSS before 1972. Then Senator Sam Nunn's investigation of the Army in Europe paved the way for replacing support troops with combat troops to "cut fat" and increase firepower. The Senator was joined in his

effort by "Soviet watchers" who urged that we strengthen our combat forces by improving our tooth-to-tail ratio. Writing for such prestigious journals as the Strategic Review in the early 1970s, these observers extolled the virtues of what they perceived as an efficient Red Army with a high combat-to-support ratio. "If they can do it, why can't we?" went the argument.

What was overlooked was the unique Red Army version of the "Total Force Policy," the close identification of Soviet society with the military. The Red Army has been able to count on direct support from the economy in peace and war since World War II. Consequently, comparisons between Soviet and US active duty CSS are misleading. Further, the Soviet watchers overlooked major differences in missions, disparate distances between home bases and troops deployed in Europe, and peculiar demands placed upon the support systems of both armies by politics and society. Such shallow analysis of the two armies' differing support requirements helped to obfuscate evaluation of US Army CSS on its merits. Into 1973, tooth-to-tail comparisons skirted the real issue: how much CSS our Army needed to win in combat.

Failure to prevent additional transfers of CSS missions into the reserve finally caught up with the Army two years after the draft ended in 1973. Army CSS was reduced by the 1975 Military Appropriations bill because these simplistic comparisons made it seem that the Army in Europe was imbalanced toward support forces at the expense of fighting capability. However, by 1975 the steady stream of men into the reserves had slowed to a trickle. Independent studies generally proclaimed that the reserves would be ineffective without a long lead time between mobilization and entry into combat. Nevertheless, 60 percent of the Army's CSS capability was entrusted to the Army Reserve and National Guard.

Since 1975 two additional arguments for the reduction of active-component CSS have developed. One is the short-war thesis, which obviates any need to mobilize reserves, and the other is host nation support (HNS), which assumes host nations will play support tail to the US combat tooth. Short-war advocates contend that the US Army would have to fight with whatever it had available in Europe since any European war would end before the reserves could react. The Army's main hope for combat support services, according to short-war advocates, must be HNS. We couldn't afford to station all the necessary CSS in the active forces, they say, and spending to prepare for a sustained war would be a waste. We should spend our money instead on whatever will improve our chances of winning the

first battle. Unfortunately, such arguments overlook the possibility that victory in the first battle could lead to second and third battles. What would happen if the Army concentrated on a short war that turned out to be no more than a violent transition into protracted conflict?

No one can doubt that HNS will be essential in either a short or a long war. However, it should be equally clear that there are practical limits to the amount of CSS the Army can obtain from a host nation, for example, the Federal Republic of Germany (FRG). Further, the FRG is certain to experience a rapidly increasing need for its citizens to provide CSS for its own forces. Any war in Europe will be accompanied by mass confusion, and the allies cannot afford to waste resources because of a lack of adequate CSS, especially during the early stages of combat when both sides are striving for immediate supremacy on the battlefield.

The major reductions in CSS since 1975 have not resulted from any unwillingness on the Army's part to prevent them. Instead, CSS planners lost their case for lack of adequate analytical tools. They based their analyses, and their case, upon Tables of Organization and Equipment (TO&E) which were in turn based upon obsolete and undocumented Manpower Authorization Criteria (MACRITs). Thus, experts outside the Army have understandably questioned the validity of CSS requests.

## POSSIBILITIES FOR IMPROVEMENT IN CSS

### Improved TO&Es

Updated TO&Es can be valid planning guides. However, realistic plans in times of austerity must be based upon current knowledge about minimum essential functions to do the job. TO&Es by nature engender a certain rigidness that may no longer be acceptable. Perhaps it is time to reconsider our methods of constructing TO&Es.

### Improved Coordination

The CSS problem is compounded by the numerous commands and staffs that influence service support--DARCOM, Logistics Center,

TRADOC, service schools, DA Staff. During World War II the Army floundered through a similar problem because no single agency was charged with consolidating and analyzing all the data accumulated by the technical services. We need a responsible, high-level organization with enough authority to translate its analyses into concrete accomplishments. The high-level analytical team could assure that CSS doctrine and materiel were conceptually integrated with other Army doctrine.

## Improved Flexibility of CSS Units

The development of task oriented forces to meet the CSS needs of the 1980s and 1990s is overdue. No CSS organization or doctrine should be sacrosanct. There is little wisdom in insisting that all service support units be identical worldwide. CSS personnel must be trained, however, to respond in any environment, since flexibility in the use of manpower is as important as having development guidelines for flexible forces. Mechanics, as an example, should be trained to function equally as well in the desert as in the jungle. It will take longer to acquire such expertise, and refresher courses will be needed to maintain skills, but the dividends will justify the expense. More equipment peculiar to the needs of extreme geographical and climatological conditions would have to be available. But a page could be taken from the Soviet text: store such specialized equipment and supplies in the areas where they are most likely to be needed, except for the relatively small amounts of such material that will be needed elsewhere for training.

Greater flexibility could be achieved by broad-based training for all soldiers. For instance, most soldiers could learn to drive trucks. Further, each soldier should have basic knowledge of fuel-dispensing pumps. In Europe and other industrialized areas, fuel availability is not a problem, but distribution may be. Pumps in the hands of troop units could be used to take advantage of fuel in such places as gas stations, factories, and large apartment buildings.

We should also study those positions having low priority during a crisis, such as administrative, financial, and computer. Personnel in these positions should be trained and programmed to assume certain other tasks that are critical in wartime but kept understrength in peacetime by practical constraints. For instance, it would be a waste of manpower to station in peacetime Europe all the ammunition handlers required for war. In a pinch, though, many

soldiers could perform this labor locally once they learned what is expected. Some units in Europe are already doing these things, but guidance is needed from Headquarters, Department of the Army, so that ideas flourish at the troop level. These efforts will not alleviate all CSS shortages, but planning and practice could save the day should plans for HNS or other assistance fail to materialize quickly enough during crises.

## Improved Analysis

Service support in the Army must be evaluated using the latest analytical tools. Quantitative methods can help define objectives and evaluate costs and effectiveness by allowing the analyst to strip away side issues and reduce complex problems to manageable proportions. However, we must not forget that important CSS goals such as trust, confidence, devotion, and morale will not submit to quantitative analysis. All analysts must be sensitive to these goals and to changing circumstances, keeping in mind that judgment and experience must inform the responsible user of formulas, graphs, and charts.

It is unlikely that all the resources needed for a contingency will be available at the outset of war. The Army of the 1980s and 1990s must be prepared to shift scarce assets to any part of the world. Therefore, CSS planners need to anticipate support requirements for a spectrum of conflict scenarios, worldwide, and they need a system to assess the consequences of shifting CSS resources from one plan to another. Otherwise, they may find themselves in a crisis groping for answers.

The model sketched in Appendix A is one tool that may be useful in the much-needed analysis. I recommend an independent study group be formed to investigate the possibilities for measuring CSS functions in relation to combat power using analytical tools similar to this model. Once the weighted importance of CSS is known, resource allocations can be made on a more rational basis, and the US Army can address itself to the goal of being the best-supported fighting force in the world.

## APPENDIX A

## FORCE RELIABILITY MODEL: A CONCEPTUAL TREATMENT

This conceptual model is intended to clarify key issues bearing on the adequacy of combat service support (CSS). The model is a much-simplified representation of CSS conditions in Europe. It permits statistical analysis of the adequacy of CSS for US Army Europe in three different situations. Data used in the computations are illustrative only. The formulas, however, are applicable to factual data.

### MEASURING THE ADEQUACY OF CSS IN PEACETIME

The model's important variables, sources of CSS and kinds of combat, are indicated in Table A-1. I assume four sources of CSS for US combat forces in Europe: US Army active component (AC) units stationed in Europe; host nation support (HNS) already under contract and performing; additional HNS to be provided during mobilization; and US Army reserve component (RC) CSS units that are scheduled into Europe. The subscript "j" designates the j-th provider of CSS: US Army AC is $j=1$; HNS is $j=2$; mobilization HNS is $j=3$; US Army RC is $j=4$. To complete the grid's vertical axis, I consider three kinds or levels of combat--peacetime, short war (or initial hostilities), and long war (or subsequent hostilities). The object in each case is to compute an <u>Index of CSS Mission Success</u>, the ratio of the total expected output of CSS in a given scenario to the total demand for CSS. If the ratio is less than one, there is a shortfall in CSS. Table A-1 should be interpreted as applying to CSS for some specified US force, say a division slice, that is already deployed in Europe. From the sequel it will be clear how CSS for subsequent reinforcements could be handled.

The <u>planned capacity</u> of j-th provider with respect to all CSS services and commodities is denoted by $c_j$. For the sake of simplicity, the US Army AC is given 100 <u>work units</u> to complete ($c_1=100$ in all three scenarios). A work unit is simply a unit of

TABLE A-1.

THE CONCEPTUAL MODEL APPLIED TO THREE SCENARIOS

MAJOR PROVIDERS OF CSS

| | | | USA Active j=1 | HNS Contract j=2 | HNS Mobil j=3 | USA Reserve j=4 | Totals | |
|---|---|---|---|---|---|---|---|---|
| PEACETIME | <u>Planned Capacity</u> (Work Units) | cj | 100 | 10 | NA | NA | $\bar{c}$=110 | |
| | Efficiency | ej | 0.9 | 0.9 | NA | NA | | |
| | Reliability/ Availability | j | 1.0 | 1.0 | NA | NA | | ACTUAL DEMAND |
| *INDEX=0.99 | Expected Output (cj.ej.rj) | Oj | 90 | 9 | NA | NA | $\bar{O}$=99 | $\bar{D}$=100 |
| SHORT WAR | <u>Planned Capacity</u> (Work Units) | cj | 100 | 10 | 30 | NA | $\bar{c}$=140 | |
| | Efficiency | ej | 1.0 | 0.8 | 0.6 | NA | | |
| | Reliability/ Availability | rj | 1.0 | 0.7 | 0.5 | NA | | ASSUMED DEMAND |
| *INDEX=0.38 | Expected Output (cj.ej.rj) | Oj | 100 | 5.6 | 9 | NA | $\bar{O}$=115 | $\bar{D}$=300 |
| LONG WAR | | cj | 100 | 10 | 30 | 100 | $\bar{c}$=240 | |
| | | ej | 0.9 | 0.6 | 0.8 | 0.8 | | |
| | | rj | 1.0 | .5 | 0.9 | 0.9 | | ASSUMED DEMAND |
| *INDEX=0.75 | | Oj | 90 | 3 | 21.6 | 72 | $\bar{O}$=187 | $\bar{D}$=250 |

*Index of CSS Mission Success = (total expected output) ÷ (demand) = $\bar{O}$ - $\bar{D}$

measure for the task to be completed within a specified time, e.g., one week. Offloading Class I supplies (food) may be one work unit; delivery from the docks to the warehouse may be a second work unit; unloading the trucks and storing the Class I may be a third; inventory and dispatch of the information to the commodity manager may be a fourth work unit; and so forth. In essence, the planned capacity of a CSS military unit is what its TO&E was designed to accomplish; the planned capacity of HNS is what the peacetime contract or mobilization plan was intended to provide. The model distinguishes two factors that can make a CSS operator's <u>actual</u> output fall below its planned capacity.

<u>Efficiency</u> is very important and shows up in the model as "$e_j$." On a scale of 0 to 1, the US Army AC is assigned an average efficiency factor of .9 for peacetime ($e_1$ =.9). Human error, learning-curve problems, sickness, leave, etc., prevent the maximum from being assigned. Here .9 is a judgment factor but it could be based on more objective criteria such as historical data or performance on tests.

None of the above has any meaning if the operator is not reliable or is not available. <u>The reliability/availability factor</u> is symbolized by "$r_j$" in the model. The active Army is assigned a factor of 1.0: it is there, on the ground, and is expected to be available in peace and war, so $r_1$ =1.0. (In principle an overstrength unit could be assigned a reliability/availability factor greater than 1.0.)

The <u>expected output</u> of the j-th provider, denoted by $o_j$, is the product of its planned capacity ($c_j$), its efficiency ($e_j$), and its reliability/availability ($r_j$):

$$o_j. = c_j.e_j.r_j.$$

Thus, the US Army AC is supposed to complete 100 work units if everything goes perfectly all the time. Realistically, its output will be lower because the Army's efficiency is not perfect. The Army AC is very reliable/available, however. In peacetime the expected output of the US Army AC is

$$O_1 = c_1.e_1.r_1 = 100 \times .9 \times 1.0 = 90 \text{ work units.}$$

That is, out of 100 <u>planned</u> work units, one can expect the US Army AC to complete 90.

The same considerations apply to the other sources of CSS, whatever the scenario. In the peacetime scenario, neither mobilization HNS nor the US Army reserve component plays a role. The US Army active component has already been discussed. Since it was recognized that the active Army could not satisfy the actual demand of 100 work units in peacetime, the shortfall of 10 work units was contracted out to HNS ($c_2$=10). In peacetime, HNS (contract) is accorded the same efficiency and reliability as the US Army AC, i.e., $e_2$=.9 and $r_2$=1.0. The expected peacetime output of contract HNS is therefore

$$O_2 = c_2 \cdot e_2 \cdot r_2 = 10 \times .9 \times 1.0 = 9 \text{ work units.}$$

Thus, of the 10 work units assigned to HNS (contract), 9 are completed because the contractors are not perfect either. The total expected output, $\bar{O}$, of the two CSS providers in this peacetime scenario is

$$\bar{O} = O_1 + O_2 = 90+9 = 99 \text{ work units.}$$

Since the total demand of $\bar{D}$ is 100 work units, the peacetime *index of CSS mission success* is 99 ÷ 100 = 0.99. In other words, the combined efforts of the US Army (AC) and HNS (contract) can complete 99 of 100 required work units for a peacetime success index of 0.99. If this were the result using real data, the CSS situation in Europe would be satisfactory unless the small CSS deficit consisted of extremely critical tasks. The use of aggregated work units in Table A-1 does indeed mask the fact that some tasks are more important than others. However, the model can be disaggregated so that one can focus on particular CSS functions and commodities, as well as on individual subunits of a major provider.

## A SHORT-WAR SCENARIO

From the peacetime case we move to what is probably a worst case for CSS. The procedures used to analyze the short-war scenario are the same as explained above, but the input data are different. Once again, these are hypothetical data introduced to illustrate a methodology.

A key change is the demand. Using reports from the 1973 Arab-Israeli war and a wealth of other available information, one should be able to estimate with reasonable accuracy the work units that must be completed. The short-war demand for CSS, as assumed in Table A-1, is three times the peacetime workload.

The planned capacity of US Army units in Europe has not changed from 100 even though some significant peacetime tasks were dropped in favor of essential wartime tasks. In comparison with peacetime the efficiency of the US Army AC has increased to 1.0. Such an improvement might come from the emotional lift generated by war, longer workdays, use of personnel extended in the command who otherwise would rotate, and so forth. Reliability/availability remains at 1.0; i.e., the CSS units are present and up to strength when the war begins.

The planned work capacity of contract HNS remains at 10 work units, but its efficiency has dropped to .8 because the age and health factors take a toll on older civilians working long hours under stressful conditions. Reliability/availability is reduced to 0.7 because some contract personnel flee or report to indigenous reserve units; others are diverted to support host nation forces.

In this short-war scenario, US Army reserve forces could not be deployed in time to affect the outcome, but HNS mobilization personnel came into play with a planned capacity of 30 work units. Since the HNS mobilization personnel and units had neither practiced their wartime missions nor worked with US commanders, their efficiency is rated at .6 for the short war, although their efficiency might improve with time. One of the major problems with mobilization HNS is being sure personnel are reliable or available. Without the benefit of practice and legally binding commitments that HNS mobilization personnel will not be diverted elsewhere by the host nation, the probability that they will arrive at the right place, at the right time, ready to operate, is assumed to be .5. (This is equivalent to assuming that only half the planned contingent shows up for the war.)

Calculating the expected output $O_j = c_j . e_j . r_j$ for each short-war provider and summing the outputs, one gets a total expected CSS output of

$$\bar{O}=O_1+O_2+O_3 = 100+6+9 = 115 \text{ work units.}$$

While the total output is 82 percent of the total planned capacity (140), it is only 38 percent of the assumed demand (300). That is, the index of CSS mission success is 0.38, which is significantly smaller than the peacetime index.

## A LONG-WAR SCENARIO

One can compute the adequacy of CSS in the same manner for a long-war scenario. In Table A-1, the assumed demand for long war drops to 250 work units. This could happen from refinement of needs as the war progresses, a lower intensity of combat due to attrition on both sides, and so forth. The active US Army dips in efficiency, because of continued long hours and arrival of inexperienced CSS troop replacements. The lower efficiency of contract HNS could result from fatigue; the change in reliability could be attributed to civilians refusing to leave their homes and follow the changing boundaries of war. Note that mobilization HNS has improved in efficiency and reliability. As the war progesses this provider should settle into a routine and become more proficient in its tasks.

The US Army reserve structure makes significant contributions in the long-war scenario, but it will take some time before the reserves become fully integrated into the war. At least initially the reserves present problems of both efficiency and reliability--the latter since some scheduled units may not arrive. In all, 187 of the 240 planned work units are completed, 63 work units short of the assumed demand of 250. The index of CSS mission success is nearly double that of the short-war scenario, but the expected output is still 25 percent less than the assumed demand.

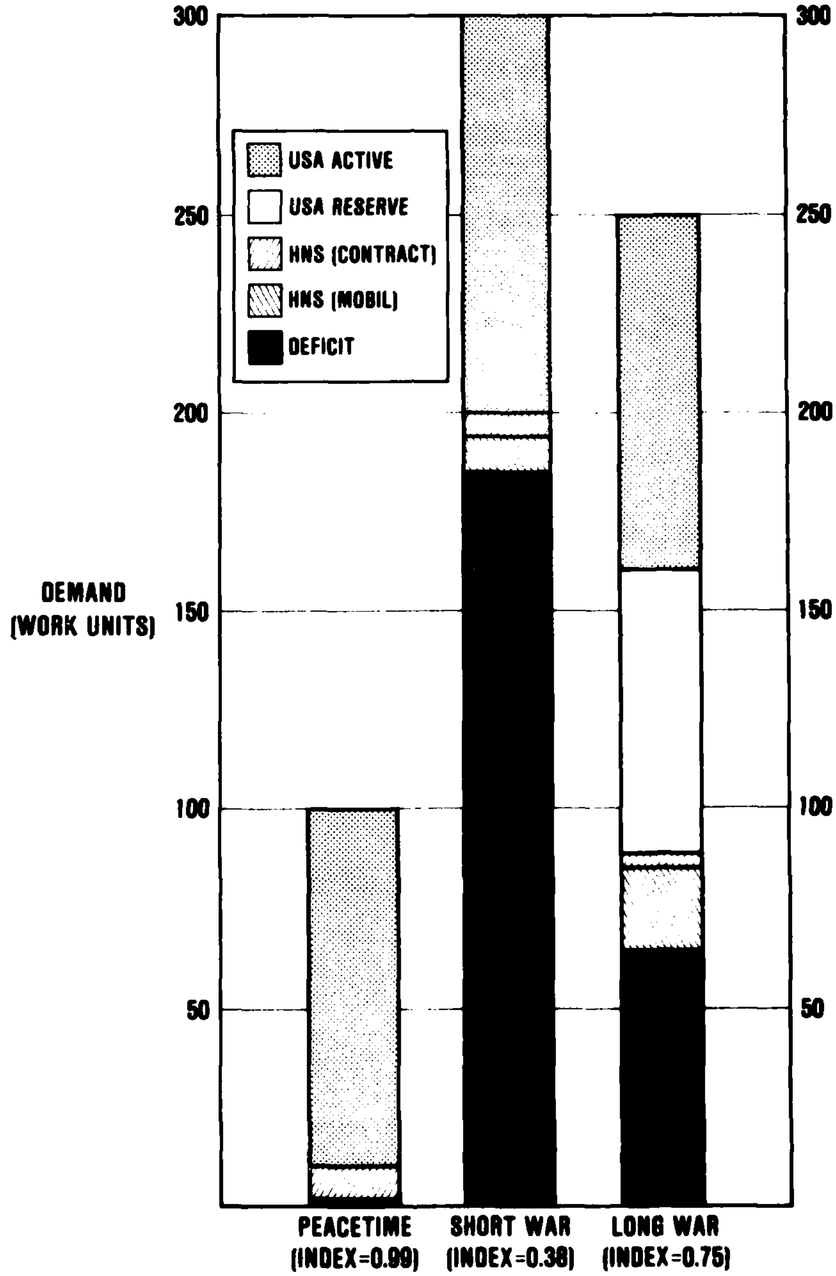
## THE RELIABILITY MODEL IN BRIEF

This general analysis of the CSS situation in Europe is just a sample of what one may expect under peacetime, short-war, and long-war scenarios. Figure A-1 summarizes CSS outputs and deficits. It shows that the peacetime CSS deficit is so small as to be hardly visible, while the deficit for a short war appears much greater than armchair analysts might have supposed.

The next logical step is to examine these deficits and decide whether they warrant corrective action. The ultimate question, of

FIGURE A-1

**SUMMARY OF CSS OUTPUTS AND DEFICITS IN THREE SCENARIOS**



course, is whether the supported combat arms can perform their missions if CSS is limited to the total expected output $\bar{O}$, because by impairing combat effectiveness, CSS shortfalls can jeopardize the allied strategy and lower the nuclear threshold.

Before going on to some observations, we summarize the logic of the model as presented so far. For the j-th major supplier of CSS we defined an aggregate planned capacity $c_j$, an aggregate efficiency $e_j$, and an aggregate reliability/availability $r_j$. All three values generally depend on the scenario of interest, as does the total demand $\bar{D}$. Then total expected output

$$= \bar{O} = c_1 \cdot e_1 \cdot r_1 + c_2 \cdot e_2 \cdot r_2 + \ldots = \Sigma\, c_j \cdot e_j \cdot r_j$$

and

index of overall CSS mission success = $\bar{O}/\bar{D}$.

At an even higher level of aggregation, one can define for each scenario a total planned capacity

$$= \bar{c} = c_1 + c_2 + \ldots = \Sigma\, c_j,$$

and then compute an overall efficiency factor $\bar{e}$ by solving the equation

$$\bar{c} \cdot \bar{e} = \Sigma\, c_j \cdot e_j.$$

The sum on the right is the output to be expected if all the major CSS providers had a reliability/availability factor of 1.0, i.e., if they were all present and on the job. The factor $\bar{e}$ is therefore the average efficiency of all the CSS providers. Having calculated $\bar{c}$ and $\bar{e}$, one defines an overall reliability/availability factor $\bar{r}$ by the equation

$$\bar{c}.\bar{e}.\bar{r}. = \bar{O}.$$

Thus, $\bar{r}$ is the average reliability/availability of all the CSS providers.

Finally, an <u>overall expected effectiveness</u> may be defined as the ratio of the total expected output $\bar{O}$ to the total planned capacity $\bar{c}$:

$$\bar{E} = \bar{O}/\bar{c} = \bar{e}.\bar{r}.$$

This ratio, which takes into account the efficiency and reliability of all the major CSS providers, indicates how well the providers are <u>expected</u> to perform as a group in relation to what the plans <u>implicitly</u> call for. The effectiveness ratio $\bar{O}/\bar{c}$ could be commendably high (close to 1.0), but at the same time the index of mission success, $\bar{O}/\bar{D}$, could be fatally low because the estimated demand in the scenario far exceeded the expected output.

## EFFICIENCY AND RELIABILITY OF HOST NATION SUPPORT

The 185-work-unit deficit in the short-war scenario is instructive. How could it be made up? There is a range of options. To make up the deficit solely with US active-component CSS would require a complement almost three times the size of the one already on station. Certainly this is not a feasible solution, at least not in the near future. Nor would it be feasible or prudent to make up such a large deficit through standby HNS contracts that would come into effect only at the onset of hostilities.

Another possibility is to arrange for additional mobilization HNS. Here the importance of efficiency and reliability becomes evident. If the 185 work units must be fully satisfied by HNS (mobilization), then an additional <u>planned</u> capacity of 185 work units will not suffice unless the efficiency and reliability of the HNS are near the maximum value of 1.0. The planned capacity would have to be "padded" to compensate for less than perfect efficiency and full reliability. Table A-2 shows the planned capacities required to deliver 185 work units of CSS for selected combinations

TABLE A-2.

PLANNED CAPACITIES REQUIRED FOR AN
EXPECTED OUTPUT OF 185 WORK UNITS

| EFFICIENCY ($e_j$) \ RELIABILITY ($r_j$) | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
|---|---|---|---|---|---|
| 0.2 | 4625 | 2312 | 1542 | 1156 | 925 |
| 0.4 | 2312 | 1156 | 771 | 578 | 462 |
| 0.6 | 1542 | 771 | 514 | 385 | 308 |
| 0.8 | 1156 | 578 | 385 | 289 | 231 |
| 1.0 | 925 | 462 | 308 | 231 | 185 |

of efficiency and reliability. For example, if the efficiency of the HNS were .8 and the reliability were .6, it would require a planned capacity of 385 work units to get an expected output of 185 work units. This is hardly realistic; one would be in the position of negotiating with the host nation for twice the CSS that one actually expected to materialize in the heat of battle.

As the computations in Table A-2 indicate, closing the short-war CSS gap with HNS (mobilization) entails an unrealistically large capacity unless US authorities could be assured of high reliability ($r_3$ close to 1.0) and high efficiency ($e_3$ close to 1.0) The question is whether these conditions can be achieved.

HNS may be a necessity, but without efficiency and, above all, reliability its value is severely limited. On the other hand, with proper planning HNS can provide a valuable diversification to the CSS structure. If a US combat unit, for example, receives half its POL through a reliable host-nation channel and half through an

independent US channel, then a complete interruption of supply is less likely than would be the case under a single-source arrangement.

## DISAGGREGATING THE MODEL

The basic ideas behind the CSS model are manifest in the three scenarios just discussed. However, Table A-1 deals with CSS at an artificially abstract and aggregated level. Each example is but the tip of a pyramid of analyses. Appendix B sketches the kinds of detailed analyses that were presupposed in the foregoing discussion.

The mission of CSS is to perform numerous distinct functions (transportation, medical care, automotive maintenance, etc.) and to furnish a myriad of commodities (food, ammunition, POL, etc.) on a day-to-day basis. Moreover, the CSS mission is carried out by many heterogeneous units and subunits, both military and civilian. The logistic analyst must address individual functions and commodities at the lowest unit level. This degree of detail is necessary: improvisation, substitution, foraging, and ingenuity can bridge some CSS gaps, but it is entirely possible to lose a battle for want of a nail. The input variables of the model--demands, planned capacities, efficiency factors, reliability factors--must be determined at the grass-roots level from the best available data. Only then can expected outputs be aggregated, combined, and measured against likely demands. Appendix B deals with the conceptual underpinnings of the gross variables in Table A-1 and shows how one can assess the adequacy of a single CSS function or commodity such as the provision of ammunition.

Table A-1 and Figure A-1 refer to aggregated "work units" of planned capacity and assumed demand; in actuality a work unit is a common measure for many different things--x barrels of helicopter fuel, y tons of artillery ammunition, z man-days of medical care, etc. The relative importance of a work unit of a particular function/commodity will vary from one scenario to another. As indicated in Appendix B, one can account for this by assigning weights to the work units of the various functions and commodities according to their importance in any given scenario.

## APPENDIX B

## DETAILS OF THE CSS RELIABILITY MODEL

As noted at the end of Appendix A, Table A-1 presents only a synoptic picture of the adequacy of combat service support (CSS) in the scenarios under examination. In this appendix we indicate how the aggregated data in the table may be derived from matrices that account for the individual services and commodities furnished by the major providers of CSS. We also show how these matrices can be used to analyze the adequacy of a single CSS function or commodity. We discuss the various options for correcting a CSS shortfall and, finally, show how Table A-1 can be made more meaningful by the introduction of weighting factors.

### FUNCTION/COMMODITY MATRICES

The matrix in Table B-1 pertains to planned capacities and assumed demands in a specific long-war scenario. The CSS functions and commodities are indexed by $i=1,2,...,n$. The major providers of CSS--US Army active units, contract host nation support (HNS), US Army reserve units, and mobilization HNS--are indexed by $j=1,2,3,4$. Thus, $d^{(i)}$ is the assumed demand for the i-th function or commodity, and $c_{ij}$ is the planned capacity of the j-th provider with respect to the same function/commodity. The demands could be based on the analysis of recent conflicts, field exercises, and simulations of the type of combat envisioned in the scenario; intelligence would be needed to establish the nature of the adversary's forces and tactics. The planned capacities are what the CSS providers are theoretically able to do at full strength by virtue of either military tables of organization and equipment or the contract specifications respecting HNS. The demands and capacities, which apply to some specified time period, would be expressed initially in conventional units (tons of ammunition, barrels of POL, etc.) and then converted to common work units of equivalent effort.

Corresponding to Table B-1 are a matrix of estimated efficiency factors $e_{ij}$, and a matrix of estimated reliability/availability factors $r_{ij}$. (These two matrices would not have the last two

TABLE B-1.

FUNCTION/COMMODITY MATRIX FOR CSS DEMANDS
AND PLANNED CAPACITIES IN A SPECIFIC SCENARIO

MAJOR PROVIDERS OF CSS

| CSS FUNCTIONS AND COMMODITIES | USA ACTIVE $j=1$ | HNS CONTRACT $j=2$ | HNS MOBIL. $j=3$ | USA RESERVE $j=4$ | TOTALS | ASSUMED DEMANDS |
|---|---|---|---|---|---|---|
| AMMO $i=1$ | $c_{11}$ | $c_{12}$ | $c_{13}$ | $c_{14}$ | $c^{(1)}$ | $d^{(1)}$ |
| POL $i=2$ | $c_{21}$ | $c_{22}$ | $c_{23}$ | $c_{24}$ | $c^{(2)}$ | $d^{(2)}$ |
| MEDICAL $i=3$ | $c_{31}$ | $c_{32}$ | $c_{33}$ | $c_{34}$ | $c^{(3)}$ | $d^{(3)}$ |
| AUTOMO-TIVE | | | | | | |
| MAINTE-NANCE $i=4$ | $c_{41}$ | $c_{42}$ | $c_{43}$ | $c_{44}$ | $c^{(4)}$ | $d^{(4)}$ |
| $i=n$ | $c_{n1}$ | $c_{n2}$ | $c_{n3}$ | $c_{n4}$ | $c^{(n)}$ | $d^{(n)}$ |
| TOTALS (work units) | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $\bar{c}$ | $\bar{D}$ |

$c_{ij}$ = planned capacity of the j-th provider with respect to the i-th function/commodity

$d^{(i)}$ = assumed demand for the i-th function/commodity

columns of totals and demands nor the bottom row of totals.) The matrix entry $e_{ij}$, for instance, is the efficiency of the j-th provider's units which are responsible for furnishing some or all of the i-th function/commodity. Specifically, $e_{ij}$ is the fraction of the capacity $c_{ij}$ that the units, if present and at full strength, could be expected to discharge under the circumstances of the scenario. The efficiency factors would be based objectively on peacetime performance and subjectively on judgments as to how the pressures and confusion of warfare would affect the CSS units.

A reliability/availability factor $r_{ij}$ may be construed as the probability that the unit concerned will be present at full strength, ready to perform its mission; this is the "reliability" interpretation of $r_{ij}$. Alternatively, $r_{ij}$ may be interpreted as the fraction of the unit that is likely to be available. Conceptually, $r_{ij}$ would be greater than 1.0 if the unit were present and overstrength. The fundamental assumption of the CSS model is that $e_{ij}$ and $r_{ij}$ are independent in the sense that the expected value of the j-th provider's output of the i-th function/commodity is given by the product of $c_{ij}$, $e_{ij}$ and $r_{ij}$.

The basic input variables of the reliability model--the capacities $(c_{ij})$, demands $(d^{(i)})$, efficiencies $(e_{ij})$, and reliabilities $(r_{ij})$--will differ from one scenario to another. For example, in a typical short-war scenario US Army reserve components (j=4) would not play a role, so the planned capacities $c_{i4}$ would be zero for i=1,2. . .,n.

## DERIVATION OF THE OUTPUT VARIABLES IN TABLE A-1: FOCUS ON THE MAJOR PROVIDERS

Summing the planned capacities of the CSS functions and commodities in the j-th column of Table B-1, one gets

$$c_j = c_{1j} + c_{2j} + . . . + c_{nj} = \sum_i c_{ij}.$$

This is the <u>aggregate planned capacity</u> of the j-th provider that appears in Table A-1. The <u>total planned capacity</u> of all the major providers for all the CSS functions and commodities is therefore the sum of the $c_j$:

$$\bar{c} = c_1+c_2+c_3+c_4 = \sum_j c_j = \sum_j \sum_i c_{ij}.$$

Now, the expected output of the i-th CSS function/commodity by the j-th provider is

$$O_{ij} = c_{ij} \cdot e_{ij} \cdot r_{ij}.$$

If this provider had perfect reliability ($r_{ij}$ = 1.0 for i=1, 2, . . ., n), the expected output of all his CSS would be

$$c_{1j} \cdot e_{1j} \cdot 1 + c_{2j} \cdot e_{2j} \cdot 1 + \ldots + c_{nj} \cdot e_{nj} \cdot 1 = \sum_i c_{ij} \cdot e_{ij}.$$

On the other hand, if $e_j$ were his average efficiency for all CSS functions and commodities, and if $c_j$ were his aggregate capacity, then the product $c_j \cdot e_j$ would also be his expected output (provided all his units had perfect reliability). Therefore, one can compute his aggregate efficiency $e_j$ by solving the equation

$$c_j \cdot e_j = \sum_i c_{ij} \cdot e_{ij} .$$

The resulting $e_j$ is the efficiency factor entered in Table A-1 for the j-th provider.

In reality, the j-th provider's aggregate expected output of all CSS is

$$O_j = O_{1j}+O_{2j}+\ldots+O_{nj}$$
$$= \sum_i O_{ij} = \sum_i c_{ij} e_{ij} r_{ij} ,$$

which also appears in Table A-1. To find the aggregate reliability/availablility factor for the purposes of Table A-1, one solves the equation

$$c_j \cdot e_j \cdot r_j = O_j$$

for $r_j$. That is, $r_j$ is the average reliability which is consistent with a planned capacity of $c_j$, an average efficiency of $e_j$, and an expected output of $O_j$.

Summing the aggregate expected outputs for all the providers, one gets

$$\bar{O} = O_1+O_2+O_3+O_4 = \sum_j O_j,$$

the total expected output of all CSS services and commodities in the particular scenario. The total demand for CSS in the scenario is

$$\bar{D} = d^{(1)}+d^{(2)}+\ldots+d^{(n)} = \sum_i d^{(i)}.$$

Finally, the index of overall CSS mission success is defined to be the ratio of the total output to the total demand:

$$\bar{I} = \bar{O}/\bar{D}$$

We have now derived from the function/commodity matrices all the output variables of the model that are displayed in Table A-1.

One can also define $E_j$, the aggregate expected effectiveness of the j-th provider, to be

$$E_j = O_j/c_j = e_j.r_j.$$

This ratio of expected output to planned capacity measures how well the j-th provider is expected to perform in relation to what the prewar plans call for. The effectiveness $E_j$ is a function of efficiency and reliability, but it does not take demand into account. It is $\bar{I}$, the index of success, that measures the adequacy of CSS in terms of assumed demand.

In Appendix A it was shown how one can combine $c_j$, $e_j$, $r_j$ for all the providers to get not only the total planned capacity $\bar{c}$, the total expected output $\bar{O}$ and the overall success index $\bar{I}$, but also an overall efficiency factor $\bar{e}$ and an overall reliability/availability factor $\bar{r}$ which satisfy the equation

$$\bar{O} = \bar{c}\cdot\bar{e}\cdot\bar{r}.$$

Also defined was the overall expected effectiveness

$$\bar{E}=\bar{O}/\bar{c}=\bar{e}.\bar{r}.$$

These "total" and "overall" variables pertain to the CSS operation in its entirety, i.e., they encompass all the CSS functions/commodities, all the providers of CSS, and all the demands for CSS.

FOCUS ON CSS FUNCTIONS AND COMMODITIES

In the previous section, all the types of combat service support were aggregated by column, that is, by major provider. The results, in the form of Table A-1 for example, may be helpful in explaining the overall CSS situation to high-level policymakers, but they do not pinpoint specific problems for CSS analysts. By summing data across the rows of the function/commodity matrices, one gets useful information on the expected adequacy of individual elements of CSS, i.e., the adequacy of individual services and commodities furnished by the combined efforts of all the CSS providers. In the preceding column analysis, we used the verb aggregate to describe the grouping of all functions and commodities by provider; in the following

row-analysis, we shall use <u>combine</u> to describe the grouping of all providers according to function/commodity.

Summing the capacities in the i-th row of Table B-1 yields the <u>combined planned capacity</u> for the i-th element of CSS:

$$c^{(i)} = c_{i1}+c_{i2}+c_{i3}+c_{i4} = \sum_j c_{ij}.$$

(The sum of all the combined capacities $c^{(i)}$ is the total capacity $\bar{c}$ as calculated above, both being the double sum of all the capacities $c_{ij}$.) Even if $c^{(i)}$, the nominal capacity of all the providers, exceeds the assumed demand $d^{(i)}$, there may be a deficit of the i-th CSS function/commodity when the output is discounted for inefficiency and unreliability. If the expected outputs

$$O_{ij} = c_{ij} \cdot e_{ij} \cdot r_{ij}$$

are summed across the providers, one gets the <u>combined expected output</u> of the i-th function/commodity:

$$O^{(i)} = O_{i1}+O_{i2}+O_{i3}+O_{i4} = \sum_j O_{ij}.$$

(The sum of the outputs $O^{(i)}$ is $\bar{O}$, calculated originally as the sum of the $O_j$; each is the sum of the expected outputs $O_{ij}$ for all i and all j.) The ratio

$$I^{(i)} = O^{(i)}/d^{(i)}$$

is the index of combined CSS mission success for the i-th element of CSS. (Ideally, each $I^{(i)}$ would be 1.0, i.e., expected output would match demand, and the sum of the $I^{(i)}$ would be n, the number of separate CSS functions and commodities. Thus, the ratio of $\Sigma$ $O^{(i)}$ to n could be used as a figure of merit for the overall adequacy of CSS. However, this ratio would not be as natural a measure of CSS success as the index $\bar{I}$.)

Following the pattern of the earlier column-analysis, one can calculate a combined functional efficiency factor $e^{(i)}$ from the equation

$$c^{(i)}.e^{(i)} = \sum_j c_{ij}.e_{ij}.$$

The factor $e^{(i)}$ is the average efficiency of all the providers with respect to furnishing the i-th element of CSS. One can also compute a combined functional reliability/availability factor $r^{(i)}$ by solving the equation

$$c^{(i)}.e^{(i)}.r^{(i)} = O^{(i)}$$

for $r^{(i)}$. This factor is the average reliability of the combined CSS structure with respect to the i-th function/commodity. And again, the efficiency and reliability factors can be condensed into a combined expected effectiveness relative to the i-th element of CSS:

$$E^{(i)} = O^{(i)}/c^{(i)} = e^{(i)}.r^{(i)}.$$

The success indices $I^{(1)}$, $I^{(2)}$, . . ., $I^{(n)}$ give a profile of CSS adequacy across the spectrum of functions and commodities. The profile highlights CSS strengths and shortfalls. Making judgments about the relative importance of the individual elements of CSS, the logistic force developer can allocate his limited resources to the corrective actions that will maximize the combat power of the supported forces.

An unacceptable index $I^{(i)}=O^{(i)}/d^{(i)}$ can be increased either by increasing the expected output $O^{(i)}$, which is in the domain of CSS, or by decreasing the demand $d^{(i)}$, which is in the domain of the combat arms customer and the threat he faces. A change in the threat implies a new scenario. The demand for CSS in a given scenario might decrease if the combat arms adopt improved tactics, more-lethal weapons (e.g., precision-guided munitions), fuel-efficient vehicles, and trouble-free equipment. To increase the combined expected output

$$O^{(i)} = c^{(i)} \cdot e^{(i)} \cdot r^{(i)},$$

one can increase the planned capacity $c^{(i)}$ by buying more of the same Army CSS units or negotiating for more of the same HNS. A cheaper option would be to increase the functional efficiency $e^{(i)}$ of existing providers; productivity can be raised through better organization, training, and equipment. A yet cheaper option might be to increase the functional reliability $r^{(i)}$, the most subjective of the factors which determine expected output. In the case of mobilization HNS, this task falls first in the diplomatic arena (to get ironclad agreements with the host nation) and then in the more prosaic realm of mobilization exercises.

By nature, reliability is a judgment call. In principle the planned capacities $c_{ij}$, the demands $d^{(i)}$, and the efficiencies $e_{ij}$ can be tied more or less to the real world. The reliabilities $r_{ij}$ are another matter. In fact, $1-r_{ij}$ is a measure of the analyst's uncertainty about the j-th provider being present to supply his share of the i-th CSS service or commodity. Clearly, it would be necessary to examine the sensitivity of the success indices $I^{(i)}$ and $\bar{I}$ to the reliability factors $r_{ij}$.

Before leaving the row-analysis, we remark that it could be carried one step further by analogy with the column-analysis, i.e., by aggregating the superscripted variables for all the CSS functions and commodities. However, one gets nothing new from this step. We have already seen that $\sum c^{(i)}$ and $\sum O^{(i)}$ are precisely the $\bar{c}$ and the $\bar{O}$ which were defined in the column-analysis as $\sum c_j$ and $\sum O_j$. And one can easily verify that both the sum of all the products $c^{(i)} \cdot e^{(i)}$ and the sum of all the $c_j \cdot e_j$ are the double sum of all the products

$$c_{ij} \cdot e_{ij}.$$

Therefore, the solution of the equation

$$\bar{c}.x = \sum_i c^{(i)}.e^{(i)}$$

is the $\bar{e}$ that was defined in the column-analysis as the solution of

$$\bar{c}.x = \sum_j c_j . e_j.$$

Hence one gets the same overall efficiency $\bar{e}$ for the entire CSS operation whether one approaches it from the provider point of view or the function/commodity point of view. Similarly, there is only one overall reliability/availability factor, $\bar{r}$, and only one overall expected effectiveness, $\bar{E}$.

## WEIGHTED AGGREGATES

When an analyst or decisionmaker is focusing on the individual CSS functions and commodities, he can mentally assign them priorities in keeping with the nature of the given scenario. With certain aggregates, however, the relative importance of the different CSS elements is lost in the otherwise undifferentiated work unit. This is particularly true of the aggregates in the column-analysis of the second section. Priorities can be partially restored to these aggregates (and their ratios) by assigning appropriate weights to the diverse elements of CSS. The i-th function/commodity would be assigned a weight $w^{(i)}$ according to its importance in the particular scenario. Without loss of generality we may assume that

$$\sum_i w^{(i)} = 1,$$

for the relative magnitudes of the weights are unaffected if all the weights are divided by their sum.

In peacetime, for instance, ammunition supply ($i=1$ in Table B-1), POL ($i=2$), and medical support ($i=3$) would have smaller weights--$w^{(1)}$, $w^{(2)}$, $w^{(3)}$--than in a short-war scenario. The opposite situation holds for high-echelon automotive maintenance ($i=4$). The weight $w^{(4)}$ would be high in peacetime when readiness is a paramount goal, but it might be lower in a short-war scenario because there is not enough time to cycle materiel through depots.

The weights would be directly applied only to the planned capacities $c_{ij}$ and demands $d^{(i)}$. Thus, in the column-analysis one would define the <u>weighted total demand</u> to be

$$\bar{D}' = \Sigma\, w^{(i)} . d^{(i)} .$$

A planned capacity $c_{ij}$ is replaced by the <u>weighted planned capacity</u>

$$c'_{ij} = w^{(i)} . c_{ij} ;$$

$c_j$ is replaced by the <u>weighted aggregate planned capacity</u> of the $j$-th provider, i.e.,

$$c'_j = \sum_i c'_{ij} ;$$

and the weighted equivalent of the total planned capacity $\bar{c}$ is

$$\bar{c}' = \sum_j c'_j .$$

The expected outputs of the column-analysis also reflect the weights:

$$O'_{ij} = c'_{ij} . e_{ij} . r_{ij} = w^{(i)} . O_{ij} ,$$

$$O'_j = \sum_i O'_{ij} ,$$

$$\bar{O}' = \sum_j O'_j.$$

The <u>weighted index of overall CSS mission success</u> is then

$$\bar{I}' = \bar{O}' / \bar{D}'.$$

The <u>weighted aggregate efficiency</u> $e'_j$ of the j-th provider is calculated from

$$c'_j . e'_j = \sum_i c'_{ij} . e_{ij},$$

and the <u>weighted aggregate reliability/availability</u> $r'_j$ from

$$c'_j . e'_j . r'_j = O'_j .$$

Note that the weights affect $e'_j$ and $r'_j$ only through the weighted capacities $c'_{ij}$ As the analog of $E_j$ one has the <u>weighted aggregate expected effectiveness</u> of the j-th provider:

$$E'_j = O'_j / c'_j = e'_j . r'_j .$$

Carrying out the final step of the column-analysis, one defines the <u>weighted overall efficiency factor</u> $\bar{e}'$ and the <u>weighted overall reliability/availability factor</u> $\bar{r}'$ to be the respective solutions of

$$\bar{c}' . \bar{e}' = \sum_j c'_j . e'_j$$

and

$$\bar{c}'.\bar{e}'.\bar{r}' = \bar{O}' .$$

The <u>weighted overall expected effectiveness</u> is

$$\bar{E}' = \bar{O}'/\bar{c}' = \bar{e}'.\bar{r}'.$$

On the other hand, the weighting scheme would not affect the variables $I^{(i)}$, $e^{(i)}$, $r^{(i)}$, $E^{(i)}$ in the row-analysis of the preceding section. (For example, $e^{(i)}$ is the ratio of $\Sigma c_{ij}.e_{ij}$ to $\Sigma c_{ij}$, where both sums run from j=1 to j=4. So, if instead of the $c_{ij}$ one used the weighted capacities $w^{(i)}.c_{ij}$ for j=1,2,3,4, the numerator and denominator of the ratio would have $w^{(i)}$ as a common factor.) However, in order to calculate the <u>weighted total planned capacity</u> $\bar{c}'$ from the $c^{(i)}$, one would have to apply the weights since

$$\bar{c}' = \sum_j c'_j = \sum_j \sum_i w^{(i)}.c_{ij}$$

$$= \sum_i w^{(i)} \sum_j c_{ij} = \sum_i w^{(i)}.c^{(i)}.$$

Likewise, $\bar{O}'$, the <u>weighted total expected output</u>, is the weighted sum of the $O^{(i)}$ :

$$\bar{O}' = \sum_i w^{(i)}.O^{(i)} .$$

Using weighted variables in a column-analysis would make a summary like Table A-1 somewhat more reflective of what CSS mission areas are important in a scenario, but it would be no substitute for the row-analysis profile of the combined success indices $I^{(i)}$, which points directly to the functions and commodities in greatest deficit. Nevertheless, a summary column-analysis has some utility: it can identify the providers which are potentially ineffective because of low efficiency or questionable reliability, and it can indicate where planned capacities might be increased most economically to raise the overall index of success. In practice, however, "fixes" will have to be made at the level of the detailed function/commodity matrices--by capitalizing a larger planned capacity here, by increasing some provider's efficiency in a particular mission area, and by enhancing the reliability of this or that provider unit.

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